Dust Grain Orbital Behavior Around Mars. R. C. Nazzario and T. W. Hyde, Space Physics Theory Group, Department of Physics, P.O. Box 97316, Baylor University, Waco, TX 76798-7316 USA (Ray_Nazzario@Baylor.edu, Truell_Hyde@Baylor.edu)

Introduction

The orbital motion of dust grains in the Mars system has recently become a well studied phenomena due to in-situ data from expeditions to the planet [2, 5-14, 16-18]. One possible dust grain source in the Mars system is ejecta caused by impacts of centimeter to micron size particles on the Martian moons, Phobos and Deimos. Impacts from particles larger than micron size eject dust grain clouds having both a size and velocity distribution which is not yet well known. This study tracks the orbits of such ejecta, assuming each particle to initially have a random velocity. It is shown that such velocities result in highly complicated dust particle motion, several aspects of which will be examined.

Numerical Model

Dust, upon entrance into the Mars system, is affected by a variety of forces including Martian gravity (where this model takes into account both the spherical and oblate gravitational field expansion terms), the solar radiation pressure, the solar gravitational force and the gravitational fields of the Martian moons. (The Poynting Robertson effect will be neglected due to the short timescales examined by this study.) The equation of motion of the dust can then be determined using the force equation for the particle, given to be

$$\vec{F} = -\frac{GM_m m_d}{r^2}\hat{r} - \frac{3GM_m m_d J_2 R_m^2}{r^4}\left[\left(3\sin^2\theta - 2\right)\hat{r} - \sin 2\theta\,\hat{\theta}\right] + \frac{\beta G M_s m_d}{R^2}\hat{R} + M_{sun}G\left[-\frac{\vec{r}}{R^3} + \vec{\rho}\left(\frac{1}{R^3} - \frac{1}{\rho^3}\right)\right] \quad (1)$$

The first two terms in Eq. (1) were derived employing energy considerations[1] where G is the gravitational constant, M_m is the mass of Mars, m_d is the mass of the dust particle, r is the distance from the center of Mars to the position of the particle, and $\hat{r}$ is the unit vector from Mars to the particle. The first term on the right hand side of Eq. (1) represents the gravitational attraction on the grain assuming a spherical Mars. The second term corrects this to include an oblateness term (J_2) for the Martian gravitational field with q being the angle measured from the rotational axis of Mars. The third term describes the radiation pressure force due to Solar radiation incident upon the particle with b being the ratio of Solar radiation to Solar gravity [15] which can be calculated using the equation

$$\beta = \frac{.6Q}{a\rho} \quad (2)$$

where Q is the radiation pressure efficiency (taken to 1.0), a is the radius of the particle (between 10 mm and 500 mm), and r is the density of the particle (assumed to be 2.4 g/cm^3). M_S is the mass of the Sun, R is the distance from the Sun to the particle, and $\hat{R}$ is the unit vector from the Sun to the dust particle for the radiation pressure force. In the last term $\vec{\rho}$ is the radius vector from the Sun to Mars [4]. A planetary shadowing effect was taken into account whenever the particle moved behind Mars with the planet being given an elliptical orbit around the sun in order to achieve a more realistic radiation pressure calculation.

Results

Dust particle orbits were calculated individually. Each simulation initially assumed a random velocity of 50 m/s for the dust particle relative to the parent body with the grains placed varying distances from their respective moon. For this study, an initial distance for the grain from Phobos of 20 kilometers was used while for Deimos, the particle was placed at a distance of 10 kilometers from the surface. Particles were launched into the shadow of Mars with the Sun, Mars and the Moon aligned. A fifth order Runge-Kutta method was used to run all numerical simulations.

The dust particles experienced several possible fates based primarily on their size. The Solar radiation pressure force quickly perturbed particles of approximately 10 mm into collisions with Mars on a timescale of days to weeks. Slightly larger particles (20 to 100 mm) were perturbed out of the orbital plane of the moon by the radiation pressure force and went on to achieve stable orbits about the planet of at least 15 years (the total time of the simulation). Particles larger than 150 mm reimpacted their parent body on a timescale between hours to a few Martian years.

Conclusions

The formation of a dust torus around Mars is still a valid possibility. The primary size range for particles composing such a torus is assumed to be in the range of 20 to 100 mm. The current study shows this size regime to also be the optimum range of grain sizes allowing for long term orbital stability. Current and upcoming missions to Mars should be able to determine whether or not this phenomenon actually exists [2].

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